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GAS TURBINE COLLABORATION COMMITTEE

Progress Report for February, 1943 No.16.

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I. AT POWER JETS

SUMMARY OF RUNNING TIMES

During the period covered by this report the total running time for all units was 69 hrs 02 mins distributed as follows:-

	Hrs	Mins	
W1A(2)	4	43	
W1A(3)	4	59	(1 hr 58min. flying)
W2B(3)	10	27	
W2B(4)	3	49	
W2/500(1)	36	21	
W2/500(2)	8	43	
Total running time for all superchargers up to and including February 28th ...	1,398	50	
Total flying time up to and including February 28th	26	41	

STATE OF ENGINES AT 28th FEBRUARY 1943.

W1(3)	Awaiting parts
W1A(2)	Awaiting parts
W1A(3)	At RAE awaiting parts
W2B(2)	Being assembled for temperature measurements of turbine nozzle blades.
W2B(3)	Being assembled with No.1 design turbine and nozzle ring for further experiments to determine exhaust cone pressure distribution.
W2B(4)	Being assembled with No.15 diffuser and W2/500 impeller with tip reduced to 1.2" width.
W2B(5)	Awaiting parts
W2B(6)	Awaiting parts
W2/500(1)	Being [illegible]

W2/500(2) Being erected for 25 hours flight acceptance run.

W2/500(3) Being erected for 2 hours flight acceptance run.

FEATURES OF PARTICULAR INTEREST

(1) Completion of 100 hours endurance running of Rex 78 turbine blades in W2/500(1).

(2) Performance testing of the skewed vane impeller in W2/500(1).

(3) Comparative tests on W2/500(2) between 102K flame tubes (no stub pipes) and 101A flame tubes (stub pipes).

(4) Investigation of exhaust cone pressure distribution in W2B(3).

(5) Running of W2B(3) in the new test house at Whetstone.

MECHANICAL FAILURES.

(1) Failure of W1A No.3 design blades in machined Nimonic 80 material in W1A(2) after 38 hours 05 mins. total running time.

(2) Failure of the starter pinion in the starter clutch in W1A(3).

(3) Wear of the splines of the intermediate driving shaft on W2/500(1) engine.

TESTING.

W1A(2)

This unit was used for the determination of blade temperatures by means of the optical pyrometer designed by the NPL. The experiment was brought to an abrupt conclusion by the failure of one blade which broke off about ¼" from the base. Most of the remaining blades received tip damage as a result of the failure.

Sufficient work had been done before the failure to establish the reliability of the instrument and it appears that the blade temperature was slightly higher than the design assumption (Gas temp. + 0.6 Rel.Vel. pot temp.).

W1A(3)

This unit has been used for further flight trials in E28/39 at Farnborough. On one flight the smooth running of the engine was interrupted at 29,000 ft. by two sharp explosions, like backfires, caused it is believed, by surging. The pilot continued climbing and no further trouble was experienced until 31,000 ft was reached when there was a further sharp explosion. The speed at 29,000 ft was 17,000 r.p.m. and at 31,000 ft was 16,300 r.p.m. The ambient air temperature at 29,000 ft was about -50°C and there was a slight inversion of temperature at this altitude, which would account for the fact that there was no repetition of the explosions between 29,000 ft and 31,000 ft.

The temperature of the cooling air and the turbine bearing were both on the high side and various adjustments were made to reduce these but with only limited success.

On 16/2/43 the unit failed to start and an examination showed that the starter pinion on the starter clutch had failed. Subsequent examination has shown that the top half of the turbine side of the blower casing is cracked.

(1)

The unit has also been used to investigate the air flow through a model of the No.3 augmentor. The first experiments showed considerable losses and even reversal of flow. By the addition of fairings these losses have been reduced and further improvements are in hand.

The pressure distribution in the exhaust cone of this unit has been investigated and a considerable increase of pressure (3" mercury) was discovered in front of the supporting struts. These experiments are to be repeated after the turbine and nozzle ring have been replaced by standard W2B design components.

W2B(4)

This unit was fitted with a W2/500 impeller (with tip width reduced to 1.2") and "no swirl" fixed intake guide vanes.

As compared with series W2/271A test (1) when all the major components were the same except for the impeller and the fixed intake guides, the surge speed was slightly lower at 12,090 as against 12,120 rpm (both figures corrected speeds) but the performance was improved (Nozzle dia.11.7")

	READ FROM CURVES OF CORRECTED RESULTS		W2/271A Test 1	± on W2/271A Test 1
R.P.M.	10,000	12,000	12,000	12,000
Air del.lbs/sq.in.	11.5	18.0	17.2	+ 4.6%
Air M.F.lbs/sec.	15.7	19.4	19.3	+ 0.5%
Thrust lbs.	365	563	515	+ 9.3%
Fuel lbs/hr.	657	820	773	+ 6.1%
Jet °C.	484	487	461	+ 5.6%
Specific fuel	1,800	1.456	1.501	- 3.0%

Readings with 12.3" nozzle and also with no nozzle were taken and in both these cases the surge speed was increased as compared with the W/271 series.

W2/500 No.1

The unit was rebuilt with a modified intermediate drive shaft and front bearing and after a 5 hour endurance run and performance tests the unit was stripped and rebuilt with a new impellor of the skewed vane type. This impellor had a tip diameter of 21.18" as against the standard 20.68". Up to 14,000 rpm the delivery pressure showed a slight improvement over that obtained with a standard type impellor but the increase was only such as would be expected from the increased tip speed. Above 14,000 rpm the performance fell away considerably. Performance runs with various nozzles appeared to indicate that the characteristics of the impellor are almost vertical.

Further runs were done with the impellor tip cut back in "V" shape with the smaller diameter equal to the standard diameter. No improvement was gained by this modification and the impellor is now being reduced in diameter to 20.68" prior to further running.

Meanwhile the unit was reassembled with the standard impellor and four 5 hour cycles were successfully completed. These brought the running time for this impellor up to 127 hours and for the Rex 78 blades to 106 hours.

W2/500 No.2

This unit was assembled with a Nimonic 80 bladed wheel and with integral dome air casings and stubless flame tubes. The 2 hour acceptance test was completed satisfactorily, full speed performance with an 11.9" nozzle being as follows:-

[illegible] [illegible] [illegible] Jet pipe

After some running with a modified heat shield the stubless flame tubes were replaced by the stubbed type. Performance runs were carried out and it was found that the thrust and jet pipe temperature were slightly down compared with the running with stubless flame tubes and the specific fuel consumption was slightly higher. This is to be expected owing to the lower pressure loss on the stubless flame tubes and the tests confirmed results obtained on W2B units.

The stubless flame tubes are slightly more efficient than the stubbed type but flame-length is greater and the flame sometimes reaches beyond the turbine nozzles. Until this feature is eliminated it is intended to run W2/500 units with the normal stubbed flame tubes.

Bearing Test Rig.

The bearing test rig has now been made fully automatic and a 100 hour endurance test has been carried out on an R & M thrust bearing under a thrust load of 500 lbs and a radial load of 75 lbs. using SAE 10 lubricating oil. The condition of the bearing at the end of the test was perfect.

II AT ROVERS.

Table of all running times to 28th February, 1943.

Unit No.	Use during period	Running time Feb. 1 to 28th		Total running time to February 28th	
		hrs.	mins.	hrs.	mins.
SR.102	Dismantled	0	00	40	11
SR.104	Varying turbine blades	9	15	97	12
SR.105	Dismantled	0	00	31	31
SR.106	25 hrs. test for thin oil	36	49	159	48
SR.107	Dismantled	0	00	27	33
SR.108	Wrecked due to burst impeller	0	00	2	45
SR.110	Installed in E.28/39 aircraft.	0	00	31	13
SR.111	Awaiting build	0	00	168	04
SR.112	Stripped	0	00	57	27
SR.113	Engine dismantled	0	00	91	36
SR.114	Running 25 hrs. endurance test.	21	38	69	21
SR.115	Rigging for gas analysis	1	10	79	22
SR.116	Starting tests	14	06	53	16
SR.117	Noise tests	0	36	36	09
SR.118	Test bed calibration	1	58	7	36
SR.121	Awaiting build	0	00	16	29
SR.122	Inspection after flight test	1	00	16	06
SR.123	Inspection completed after 100 hours test.	89	33	109	29
SR.124	Accessory	4	20	10	14
SR.125	25 hrs. test on thin oil.	25	02	113	16
SR.127	(Flight F9/40.	5	05	10	29
SR.128	(Engines dispatched	1	49	6	51
SR.129	Building for 25 hrs. test	7	38	7	38
SR.130	Endurance and rating test	6	23	6	23
SR.131	Final test	8	04	8	04
STX	Stripped	0	00	33	43
SR.132	Endurance and rating test	5	53	5	53
ST.1	50 hrs. endurance tests	107	20	225	40
ST.2	Test oil plain bearings	19	16	58	47
	TOTALS	506	55	1,532	06

1. Outstanding features for the month.

100 hours development test at a take-off rating of 1250 lbs. thrust. Check tests and strip examination of engine after completing 25 hours flying.

100 hours endurance test on ST.1.

2. 100 hours development test - Take-off 1250 lbs. W2B. No.123.

Engine No.123 is a Rover built W2B engine, incorporating a Rover B.23 Blower Casing and 20 Vane Diffuser. The Turbine was an 80 blade Hastelloy with blades made from stampings received from the U.S.A. The combustion equipment consisted of scoop type colanders with radially supported flame tubes and CSM9 burners, the air casings were in mild steel protected by aluminising. In all other respects the engine was to the Standard Flight Specification.

The 100 hour test was run in two 5-hour periods and nine 10-hour periods and was completed satisfactorily. At the end of 50 hours the engine support trunnions were removed and replaced by a later type on which extended running was required before clearing for introduction into the Flight Engine Specification.

No parts were changed throughout the test other than the trunnions noted above and only one inspection of flame tubes was made, this being at the end of 50 hours when 5 domes were removed and the flame tubes inspected in position. As the condition of the flame tubes and burners was satisfactory, the domes were replaced and the test continued. At various stages throughout the test burner pressure fluctuation was experienced, which was thought to be caused by the fuel pump, but it was decided not to change the pump and the 100 hours was completed on the one pump.

Throughout the test 103 accelerations were completed in an average time of 5 to 6 seconds and at no time was surge experienced. 26 starts were made, the average time per start being 15.6 seconds.

As the test was run mainly in 10 hour periods additional starts with 2 hour cooling periods were made at the end of the 100 hours in order that the total number of such starts should be the same as if the test had been run in 5 hour cycles.

The thrust curve at the end of the 100 hours running was almost identical with the preliminary curve carried out prior to starting the test, but the corrected jet pipe temperature at governed speed had increased by approximately 30°C., and the specific fuel consumption showed an increase at the same speed from 1.17 to 1.24 lbs/lb/hr.

The turbine tip clearance before and after test showed very little difference, being .049/.052 before test and .041/.049 after test.

The strip examination revealed no serious defects. The condition of the flame tubes and burners was very good and they were satisfactory for further running except that the three brackets securing the jet shield to the colander in No.8 combustion chamber were broken; the jet shield however was still firmly secured in the swirler locating groove. The flame tube and inner balance pipe locating pins were again very badly fretted. Steps are being taken to obviate these defects.

The nozzle guide vane average area had increased from +0.30% to +0.71% over standard and the diffuser had decreased in total throat area from -0.33% to -0.61% below standard.

3. Test and examination of Engine No.122 (W.2) after 25 hours Flight Trials in Wellington Aircraft.

The installation and flight trials of Engine No.122 in Wellington 3.8570/G were carried out by Rolls-Royce personnel at Hucknall. [illegible] complete [illegible] Reference:-

General Conclusions.

1. Surge tests have failed to produce any surge up to a maximum equivalent R.P.M. of 17,400.

2. 25 hours of load running have been satisfactorily completed, with little serious trouble on the unit, except for the occurrence of rather high exhaust temperatures. The reason for these should appear from an analysis of the figures now in progress.

3. The flight tests have been restricted by limitations on the ambient air temperature.

The only trouble experienced with the engine was with the starting pawls which failed during preliminary ground running at Hucknall. The exact cause has not yet been determined but it is suspected that the failure was due to the pawls coming out of mesh, owing to an intermittent electrical fault in the starter or starter circuit. The matter is still under investigation.

The flame tubes were examined after 15 hours running and the combustion equipment was found to be generally satisfactory.

The turbine tip clearance was .046" (cold) and the blades were in good condition.

The engine was removed from the airframe, returned to the Works and installed on the test bed for a check rating test and examination for surge.

It was fitted with the flight jet pipe with an integral nozzle of 11.712" diam.

While motoring over, definite clicks were heard from the fuel pump, which were coincident with knocks felt in the main fuel delivery pipe. The engine was, however, run without removal of the pump.

During the test bed running, a 30 seconds starting cycle was adhered to, as controlled by the aircraft starter panel, but no sign of the knocking in the starter was found.

In exploring for surge, the engine was run slowly up to 16,445 r.p.m. (actual) and maintained at that speed for 1 minute. Five accelerations were then made from slow running to approximately 16,000 r.p.m. in an average time of 6.6 seconds and no surge or choking occurred at any time.

The Rating Test was completed satisfactorily, and the engine was then removed from test for strip and detail examination.

4. 100 hours endurance test on ST.1.

The engine comprised Rover blower casing, 20 vane diffuser with 10°40' initial angle and T.A. 28.406 sq.ins.; air intakes with 24° nominal swirl angle; nozzle guide vane T.A. 0.02% above standard; turbine 80 "nimonic 80" blades; and plain bearings throughout. Jet pipe nozzle 11.625" diam.

(a) Two 50 hours endurance tests have been carried out successfully during the month. Each test consisted of 5 double 5-hour cycles, each "half double" cycle comprising:-

5 mins. at take-off	1288 lb.	16,500 r.p.m.
½ hr. at maximum climbing r.p.m.	1212 "	16,200 "
[illegible] at all-out level flight r.p.m.		16,500 "
[illegible] r.p.m.	[illegible]	[illegible] "

(b) Performance curves taken at the beginning and end of each 50 hour test showed only small general deterioration. Stripping of the unit after the tests revealed only small amounts of damage to minor parts.

These two tests complete three endurance tests, ea[illegible] hours duration on this Straight-Through unit, all of which were compl[illegible] actorily.

5. Running on ST.2.

The engine comprised Rover blower casing, 20 van[illegible] tial angle 10°41' T.A. 28.697 sq.ins. air intakes with 24° nominal swirl an[illegible] e guide vane T.A. 1.08% above standard; turbine with 80 "Hastelloy" blade[illegible].

19 hours 16 minutes running were carried out during February, in the course of tests in connection with minor modifications to bearings, bearing housings and lubrication system, together with starting tests.

6. Effect of modifying turbine blade angles - SR.104.

A series of tests in connection with Hastelloy bladed turbines has been concluded, and another series using a turbine with 80 "Nimonic 80" blades is in progress.

(a) Investigation of the effect of modification to the blade profile of a Hastelloy bladed turbine.

The original performance of the turbine was poor, as is shown by comparison with the performance of the engine when fitted with a Rex 78 bladed turbine. The Hastelloy blade profiles diverged from standard at both leading and trailing edges and successive modifications were made by bending these edges, to approach the correct form, the engine performance being determined at each stage.

The main engine performance data relative to the following turbines is tabulated below:-

(i) 72 Rex 78 blades. (machined to [illegible])
(ii) 72 Hastelloy fully forged blades. (not accurate to drawing).
(iii) 72 Hastelloy blades modified to conform more nearly to drawing profile by bending the trailing edge (approx. 5° at the tip) in a direction to increase the gas deflection relative to the blade at exit.

(iv) 72 Hastelloy blades further modified by bending to bring the leading edge into the correct position. The combined blade by approximately 4°, and so bringing it approximately into the standard position.

All results corrected N.T.P.

Test No.	Diffuser T.A.	Turbine	Surge Speed	Thrust at surge and	Values at 1100 lbs. thrust. R.P.M.	Spec. Con.	J.P.Temp °C
SR4/27/2	28.99	(i)	16420	1283 lbs.	15420	1.18	527
SR4/28/2	28.99	(ii)	15450	1125 "	15050	1.25	549
SR4/32/2	28.976	(iii)	15840	1253 "	15200	1.245	556
SR4/33/1	28.975	(iv)	15870	1250 "	15250	1.19	525

The above results show that the poor performance of the Hastelloy turbine was restored approximately to the standard of the Rex 78 turbine, by bending the blades to conform to Rex 78 shape.

(b) A series of tests on SR.104 to the same build as above, but with an 80 bladed Nimonic 80 turbine, is in progress to define the effect of skewing the turbine blades to various angles in the direction of decreased entry angle and increased exit angle. The results of the full series of tests will be [illegible] next month.

7. Present position of other engines.

W2B Engine No.125

This engine was a standard B.23 blower casing engine, with ZA 2555 20 vane diffuser. After completing 25 successive accelerations in an average time of 5.5 seconds each without any signs of surge, the engine was dismantled and converted to the P.J. type blower case, and 13.B 10 vane diffuser. The blower case, diffuser and air intake guide vanes used were taken from Engine No.115.

When converted, the engine was tested up to 16,420.r.p.m. (actual) and acceleration tests were made in satisfactory time, and without any sign of surge.

This engine, now as a P.J. 13.B. type engine, was started on a 25 hours Approval Test, for thin lubricating oil, but after running for [illegible] hours under Type Test conditions, the test was terminated, due to the failure of the impeller. All the blades on the rear side of the impeller had broken away, and the resulting damage had completely wrecked the diffuser and cracked the blower case.

W2B Engine No.115.

This engine was a P.J. blower case and 13.B. 10 vane diffuser engine, and it had consistently surged during acceleration tests. The engine was then converted to the B.23 20 vane diffuser type, by using the blower case, diffuser and air intake guide vanes from Engine No.115.

After conversion the engine was tested and found to surge violently at 16,340 r.p.m. (actual) under normal opening up conditions and to surge during accelerations as previously. It appears, therefore, that the abnormal surging of this engine is a characteristic of the rotating parts and is not due to the blower casing and diffuser design.

W2B Engine Nos. 127 and 128.

Both these engines completed Final Test for a take-off thrust of 1,250 lb. and have now been despatched for installation in the F9/40 Aircraft.

W2B Engine No.129.

This engine incorporates the latest B.23 blower case with integral bend ring and 20 vane diffuser and the turbine has 80 blades, fully forged Nimonic 80, 0.010" thicker at the root.

The two hours Endurance Test and strip inspection has been completed, prior to commencing a 25 hours Type Approval Test at the increased rating of 1450 lbs. for take-off.

W2B Engine No.130.

Engine has completed Final Test at a take-off rating of 1,250 lb. thrust and is to be despatched as a spare engine for the F9/40 Aircraft.

W2B Engine No.131.

This engine has completed Final Test at a take-off rating of 1,250 lb. and has been despatched for installation as the tail unit in the Wellington Flying Test Bed.

W2B Engine No.132.

The engine has completed Final Test at a take-off rating of 1,400 lb. and the engine will be held, pending the completion of the forthcoming 25 hours test on Engine No.129.

III. AT B. T. H.

UNIT 21

Modifications for the carrying out of tests with 20-vane diffuser and reduced radial clearance between impeller tip and entrance to diffuser are proceeding.

No running for period under review.

Total running time to date - 40 hours 20 mins.

UNIT 22

The turbine nozzle ring has been modified to give an exit area between 0.75% and 1.25% under calculated area.

With 12-½" diameter propelling nozzle, the following results have been obtained corrected to NTP for air temperature at entry to Venturi meter.

R.P.M.	16,290	16,100
Thrust in lbs.	1602	1550
Temperature in exhaust pipe	636.5°C	610°C.
Specific Consumption, lbs.per hour per lb. thrust	1.23	1.21

Intermittent surging occurred at a corrected speed of 16,290 R.P.M.

Consideration is being given to modifications to diffuser which may give an increase in top speed without surging.

Running time for period under review - 1 hour 53 mins.

Total running time to date - 9 hours 13 mins.

IV. AT DE HAVILLANDS

RUNNING TIMES:

Supercharger	January hrs.	mins.	Total hrs.	mins.
H.1/1001	4	3	77	48
H.1/1002	4	29	121	22
H.1/1003		31	7	32
H.1/1004		34	8	10
H.1A/1005	6	6	6	44
Total	15	43	221	36

H.1/1001.

The supercharger continued the calibration tests with straight turbine blades. Tests were run with tail pipe extensions of different diameters and these indicated that the standard diameter, 16.25", gives the best compromise between thrust and jet pipe temperature - specific fuel consumption is sensibly unaffected by this variable.

On the conclusion of this work, the turbine wheel was changed for one having the original twisted form of blades and tests were run to provide a direct comparison with the straight blades. These showed the thrust to be slightly higher with the straight blades - 3½% at 9500 RPM falling to about 1½% at 8000 RPM - and the specific fuel consumption also some 1½% higher. The jet pipe temperature was some 40° - 45°C lower with the straight blades, except at [illegible]

remote date, while the present series of tests were done under truly comparable conditions, with no other change made than the turbine wheel itself.

The supercharger is now stripped and the compressor is being prepared for calibration at Northampton.

H.1/1002.

The supercharger was rebuilt strictly to the Gloster P.9/40 standard to provide a flight spare and a 2-hour endurance test was satisfactorily run.

An oil heater coil, located on the support cylinder near to its rear end, and connected between the oil pump and the pressure filter, was tried out during the endurance run with extremely encouraging results, an oil temperature, at the metering pumps, of 66°C being maintained.

The unit was stripped and rebuilt - without the heater coil - and satisfactorily completed its final test.

H.1/1003 and 1004.

Two successful ground runs, on both units simultaneously, over the full speed range to 9000 RPM were made.

Following this the units were removed from the aeroplane and returned to de Havillands for cleaning of the combustion chambers prior to re-installation at the aerodrome for flight trials.

H.1A/1005.

The supercharger, which was assembled with the 83-blade wide-chord turbine wheel and stub-tube combustion chambers, was calibrated up to 10,000 RPM. Compared with an average calibration of No. 1002, the thrust is of the order of 6 to 8% lower throughout the speed range while the jet pipe temperature is some 30°C higher: specific fuel consumption is about 5 to 6% higher.

Tests were run on a mock-up of the Gloster aircraft fuel system for the purpose of checking the functioning of the fuel tank pressure accumulator: these are as yet incomplete.

"Daisy" type combustion chambers, with fixed-orifice burners, were fitted and a 2-hour endurance test at 7750 RPM was run. The thrust was slightly higher than with the standard chambers - about 4% - while the jet pipe temperature was some 40°C lower: it is perhaps unwise to draw any conclusions from running at a single speed and a complete calibration is awaited.

At the present time the chambers are removed for inspection prior to embarking upon a test up to 10,000 RPM.

Combustion.

The Dartford test rig is now in full working order and tests are proceeding satisfactorily on the large combustion chambers.

V. AT METROPOLITAN - VICKERS

RUNNING TIMES

The following are the running times on complete units:

Unit No.	1	2	3
[illegible]	[illegible]	[illegible]	[illegible]

No.1 UNIT

After reassembly and calibration tests, a 2-hour component approval test was run on this unit. The running was good and the performance similar to that recently obtained on units Nos.1 and 2. A strip examination followed in which everything was found in good condition except for a crack in the outlet edge of one turbine first stage fixed blade. This blade did not require replacement. The unit was reassembled, run for setting and demonstration purposes, and given a half-hour proof test. It is now being prepared for despatch to Gloster Aircraft.

No.2 UNIT.

This unit is at Gloster Aircraft for the F.9/40 installation.

No.3 UNIT.

This unit has been completely assembled in condition for installation in the Lancaster flying test-bed. The arrangement is generally similar to that of units Nos.1 and 2 but differs in the following respects:-

(1) The external auxiliaries are changed. There are no aircraft auxiliaries and electric starting is provided.

(2) In the combustion chamber the primary chamber outer wall is made double.

(3) The turbine disc, moving blades and fixed blades are in Nimonic 75 instead of Rex 78.

The unit is in the test house where it is being connected up to the RAE instrument panel which is to be installed in the Lancaster.

No.20 COMPRESSOR.

A series of tests on this compressor has been completed. This is the first double conical flare compressor. As compared with No.1 compressor, which had blading of the same section in a single flared arrangement, the efficiency of No.20 compressor is higher at low speeds but slightly lower at high speeds and both pressure rise and efficiency characteristics are less peaked at low and intermediate speeds. A unit with this design of compressor should therefore be easier to start than No.1 unit and should have a greater margin against stalling.

VI. AT ROLLS - ROYCE

1. BLADE TESTING RIG.

The set of cast vitallium blades (C.R. type) has so far completed 20 hours of the proposed 50 hour endurance run at 6,500 rpm and 850°C gas temperature, measured at the outlet from the turbine. So far the blades have given no sign of trouble, though progress has been hindered by rig defects. Incidentally the combustion chamber used for these tests (an 18 inch C.R. type) has so far proved trouble-free and in the course of the runs a maximum heat release rate of nearly 2 x 10⁷ C.H.U. per cu.ft. per hour per atmosphere has been reached with a combustion efficiency of at least 95%.

2. C.R. UNITS.

C.R.1.A. has now been run up to a compression ratio of nearly 2:1, but at present acceleration beyond this point is prevented by the onset of fouling of the inter-rotor seals together with stalling, although the cold seal clearances have been increased to about 0.015 in. in an effort to cure the trouble. The [illegible] that the [illegible] for [illegible]

unit, using the 27 inch combustion chamber, to check this point.

It is also intended to twist the blades of C.R.1.A to compensate for the smaller deviation obtained with the closer blade spacing. This will be done to allow for the possibility that the fouling is preceded by, and in some way caused by, the stalling. If so, the twisting will either cure the trouble or transfer it to a different compression ratio.

Up to the point of breakdown the running of the unit is quite satisfactory. There is little noise and air flow and compression pressure are rock-steady. Allowing for the leakage loss through the large seal clearances now used the combined efficiency appears to be up to expectation.

Cascade Tests.

Tests at design incidence on turbine cascades corresponding with the 46-bladed and 60-bladed rotors have now been completed. In both cases the loss varies inversely as the square root of Reynold's number, suggesting that the flow is laminar. Optimum efficiency would be obtained with a spacing intermediate between the two tested. The closer spacing has about 4° less deviation than the wider one.

The running time on C.R.1.A. during the month was:-

2 hours 57 mins. blown and 2 hours 28 mins. power.

Total time: 18 hours 36 mins. blown and 17 hours 47 mins. power.

The running time of the coupled rotor test rig was 11 hours 46 mins.

3. W.R.1. Unit.

Month's running time 6 hours 49 minutes.

Total running time 18 hours 07 minutes.

The cracking of the combustion equipment previously reported is attributed to the high amplitude pressure variation (at impeller blade frequency) in the compressor delivery. To deal with this the impellor tip clearance has been increased from 0.5" to 1.0" by cropping 1.0" from the impellor diameter and a set of combustion equipment in heavier gauge material has been ordered. The running during the month has been carried out with the original combustion equipment which has been strengthened and repaired as far as possible in order to obtain performance measurements for the cropped rotor and to continue the investigation into the pressure pulsations.

The maximum conditions reached were:-

10,400 RPM 1,975 lb. Thrust. 1.33 lb/hr/lb.Sp.Cons. (Corrected values)
630°C Actual jet pipe temperature;

these figures were obtained with the oversize, 15.9" dia. jet pipe. To compensate for the cropping of the impellor the engine maximum speed has been raised from 10,000 to 10,500 RPM.

A direct comparison of the amplitude of pressure fluctuation before and after cropping the rotor is not at present available as it has been found that resonance effects are present at certain speeds but, even with the cropped rotor, the pressure variation is severe (of the order of ± 15 lb/sq.in) on a compressor delivery pressure of 20 lb/sq.in. gauge.

VII, AT R. A. E.

Work on the short annular combustion chamber which is similar to the type in use on the first three P.2 engines, has shown that in spite of a good deal of visible flare at the outlet the combustion efficiency, by direct loss measurement, is about 94% at air/fuel ratios of 67:1 and 80:1. The radial temperature gradient is still extremely steep. The absence of the double wall to the primary zone did not have any deleterious effects.

Work on the modified original P.2 annular combustion chamber has been resumed.

An alternative method of direct measurement of combustion loss has been developed and is giving promising results. A comparison with the Cambridge analysis on the P.2 rig gave close agreement. The method is based on the measurement of the net and gross percentages of CO_2, where the net concentration is that in a water cooled sample and the gross value is that obtained after burning all the residual combustibles. The combustion loss is given by $\frac{(CO_2\% \text{ gross} - CO_2\% \text{ net})}{CO_2\% \text{ gross}} \times 100$, an expression which yields a value of efficiency accurate to ±1.5% in 95% of all cases so far examined. The method has the advantage of needing only the estimation of carbon dioxide which can be determined with great precision.

The W1A No.3 was flown in E.28/39 with a calibrated pitot tube in the jet pipe, and tests have included a climb to 31,000 ft. and climbs, dives and levels at 15,000 ft. The flying time during the month was 1 hour 58 mins.

During the climb a surge was experienced at 29,000 ft. and again at 31,000 ft. The freedom from surging between the two heights was accounted for by a temperature inversion. The minimum oil temperature was +8°C and a high turbine cooling air temperature was recorded, rising to 255°C at 31,000 ft.

In view of the high rotational speeds attained, the surging and high cooling air temperatures, a partial strip was undertaken. The turbine blading was in a satisfactory condition and the unit was reassembled after reducing the clearance of the duplex air seal adjacent to the turbine disc rim from 0.075 in. to 0.062 in. as it was considered that the high cooling air temperatures might be due to excessive clearance on the air seal or to the modified disc fan blade design.

After a further flight test at 15,000 ft, it was found impossible to start up the engine and examination showed that the starter pinion which meshes with the high speed pinion had stripped its teeth and caused damage to the remaining gears.

A complete strip revealed a cracked top half rear blower casing caused by an old impeller rub. A new casing is being machined and the complete unit reconditioned.

An analysis of the thrust figures obtained showed the results to be remarkably consistent when plotted in a non-dimensional form and gave at a rotational speed of 17,000 rpm in the static condition a thrust law of

$$\text{Nett thrust} \propto (\text{rel. density})^{0.84}$$

The correlation of fuel consumption figures was poor and in comparison with the bench test results, yielded consistently high values. This throws some suspicion on the burner pressure method of fuel flow measurement. Compressor temperature rise results were very scattered owing to fluctuations in the intake temperature measurements, whereas the compressor pressure ratios plot was fairly good.

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[redacted]

This refers to our letter to you dated October 7, 1999, regarding your appeal to the Information Security Oversight Office for 14 documents previously requested under Mandatory Declassification Review procedures. One document (AD346727) was provided to you by our letter dated November 19, 1999.

The review of 11 British documents you requested is complete and there are no objections to release. Titles of these documents are contained on the enclosed sheet and a copy of each is enclosed. We will advise you as soon as the reviews of the remaining two documents are completed

Per DoD letter, Please mark these 11 documents "available to the public."

I verified the docs could be marked available for public release via telecon with Pat Skinner, DoD Security Review, 695-9556/6428 on 21 Jan 2000.

Kelly Akers
DTIC-RS

Sincerely,

SIGNED

H. J. McIntyre
Director

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